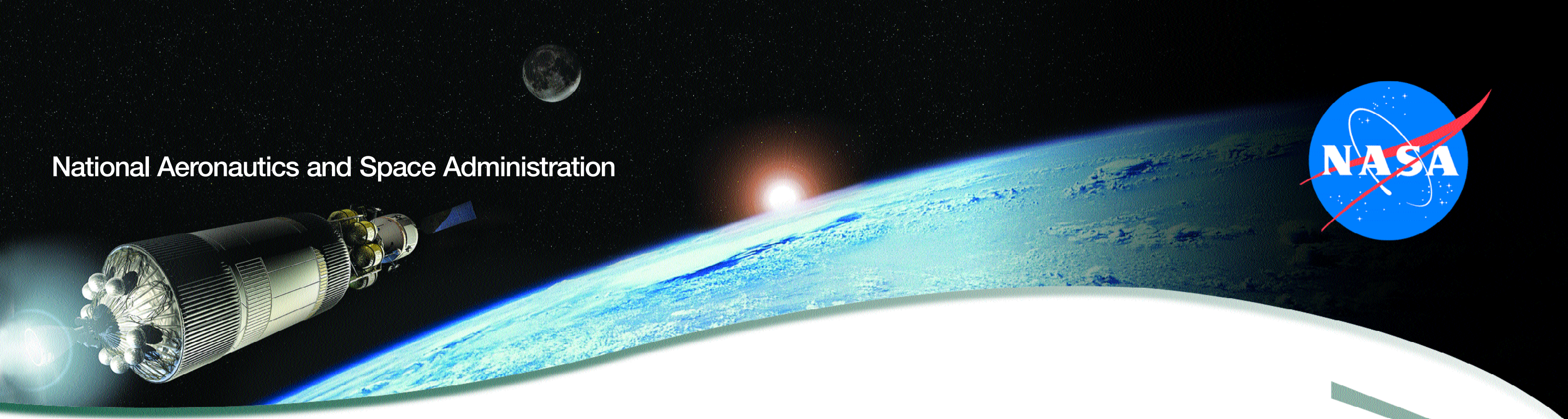

Vacuum Pyrolysis

Creating Breathable Air and Rocket Propellant

About the Technology

Vacuum pyrolysis is an efficient technique for extracting oxygen bound up in lunar soil and rock. Instead of using chemicals to reduce the oxygen, vacuum pyrolysis incinerates the rock or soil at high temperatures in a vacuum. Recent demonstrations have shown that the required temperature to release the oxygen is much lower than previously thought, only 1200°C. Under these temperature conditions, the soil vaporizes and releases gaseous oxygen that then can be pumped and stored in holding tanks for breathing or for rocket propellant.

Below: Vacuum pyrolysis uses heat to incinerate lunar soil and rock to extract oxygen bound up in the regolith. Recent demonstrations have shown that the required temperature to release the oxygen is much lower than previously thought.

Significance of the Technology

Producing oxygen in situ offers substantial cost savings to NASA. Liquid oxygen is about 80% of the propellant mass. If liquid oxygen were used as the propellant for return trips to Earth, NASA would benefit from a significant savings in mass.

Research also indicates that vacuum pyrolysis is significantly more efficient than other techniques. Analysis shows that the technique may be capable of producing 16 tons of oxygen per month, compared with 2 tons using reduction methods, assuming the same amount of regolith is processed. It also requires little infrastructure, takes advantage of the Moon's natural resources, and does not require consumable reagents from Earth.

See reverse side

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Vacuum Pyrolysis

Benefits of the Technology: At-A-Glance

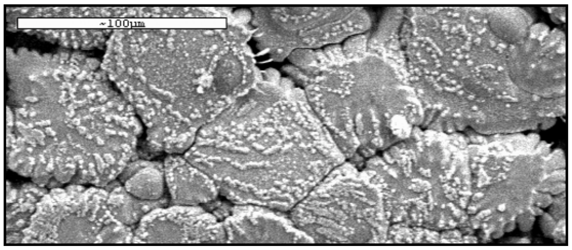
- Offers much greater efficiency compared with other techniques because it is a much simpler process. The plant requires fewer parts.
- Supplies oxygen for both breathing and rocket propulsion. Consequently, NASA would not have to transport oxygen needed for operations on the Moon. NASA could instead manufacture it there.
- Produces more oxygen per pound of regolith mined than other processes.
- Takes complete advantage of the resources of the lunar environment, which offers a natural vacuum and high-solar flux. In addition, any type of lunar regolith can be used to manufacture oxygen.
- Requires no imported chemicals.

How the Technology Works

A lunar processing plant would collect oxygen-rich soil, place the material inside the plant's reactor, and use concentrated light, resistive heating, or microwave energy to heat the soil to about 1200°C in a vacuum. At those temperatures and pressures, the soil vaporizes, releasing gaseous oxygen that the processing plant would capture and store in holding tanks. Performance predictions indicate that vacuum pyrolysis could produce more than 1 kg of oxygen per 10 kg of regolith processed, which is 10 times more than with reduction techniques.

To demonstrate the concept, Goddard technologists have developed a prototype system equipped with a large Fresnel lens that concentrates solar light before it passes through a window and into a vacuum chamber where it heats simulated lunar regolith. The soil vaporizes and decomposes, ultimately releasing oxygen. Run times of up to one hour have successfully vaporized and condensed several lunar-simulant materials, and measurements indicate that the technique is producing small quantities of oxygen.

Since demonstrating the system, researchers have built a larger prototype that uses a large parabolic reflector to concentrate light from the Sun. The Goddard In Situ Resource Utilization (ISRU) team also has developed and demonstrated a vacuum-pyrolysis chamber that uses resistive heating.



This image shows the incinerated remains of the lunar simulant.

Technology Origins

Although a significant amount of research has been done on ilmenite reduction — an oxygen-extraction technique that uses chemicals as part of its processing — comparatively little has been done on vacuum pyrolysis. Because vacuum pyrolysis requires less hardware and can process all types of lunar soil, Goddard researchers decided to investigate the approach in more depth. They received Goddard Internal Research and Development funding to build several prototypes. Although the research has yielded results, the technique remains less mature.

Looking Ahead

Goddard currently is developing the Sample Analysis at Mars (SAM) instrument suite. The ISRU team is now collaborating with the SAM team to develop vacuum pyrolysis for the Volatile Analysis by Pyrolysis of the Regolith (VAPoR) instrument to demonstrate the technology for a possible flight to the Moon.

Contact:

Eric.H.Cardiff@nasa.gov

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